Unmanned Aerial Vehicle Camera Integration

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In recent years, Unmanned Aerial Vehicles (UAVs) have provided a bird?s eye view of the battlefield with onboard video cameras feeding video images back to a ground control station. This paper reports on a project conducted by members of the Air Force Academy?s UAV Research Group to purchase equipment and build an integrated video capture system for a small UAV. This project was funded by a grant from the Institute for Information Technology Applications (IITA).

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ABSTRACT

In recent years, Unmanned Aerial Vehicles (UAVs) have provided a bird's eye view of the battlefield with onboard video cameras feeding video images back to a ground control station. This paper reports on a project conducted by members of the Air Force Academy's UAV Research Group to purchase equipment and build an integrated video capture system for a small UAV. This project was funded by a grant from the Institute for Information Technology Applications (IITA).

Introduction

Unmanned Aerial Vehicles (UAVs) have been put to the test in recent conflicts. The expanding development of UAVs provides an opportunity to change the way modern warfare is conducted [1]. There are many UAV systems currently being used in the DoD ranging from large systems, such as the Global Hawk, to small systems based on model airplane-sized UAVs. One of the most common payloads for a UAV is a video camera and a video feed back to the ground control station providing a bird's eye view of the battlefield.

The UAV Research Group (UAVRG) at the Air Force Academy currently consists of over 25 members from eleven different academic departments. Over the past three years, we have gained experience in small UAVs such as the Desert Hawk UAV [2], designed by Lockheed Martin, and the Silver Fox UAV [3], developed by Advanced Ceramics Research (ACR). We have continued to expand our expertise with these UAVs and have developed a flying test bed that can be used to test UAV applications using real UAVs. We are using aircraft in the test bed that are less expensive than the operational UAVs, but still based on the Piccolo autopilot module [4], the same autopilot used in the Silver Fox.

Under a grant from Institute for Information Technology Applications (IITA), the UAVRG has purchased equipment to capture video from an airborne UAV. The purpose of this project was to learn more about the limitations and benefits of video cameras, video capture hardware and software, and digital storage capacities. This paper serves as the final report for this project and describes the equipment that was purchased and the integration of this equipment into a video capture system. It also describes how the camera was physically mounted onto the UAV and the limitations we encountered. The paper also reports on experiments that the cadets in the Software Engineering class conducted in order to compare the different video compression and storage algorithms available for the system. Finally, this paper suggests future directions and research in this area.

System Components

As part of this project, the UAVRG purchased the following major components that comprise a video capture system: a video camera small enough to be mounted on a UAV; a video transmitter and receiver pair; a video capture device that can connect the video receiver to a computer; and video capture software that runs on the computer. Figure 1 shows these major components.

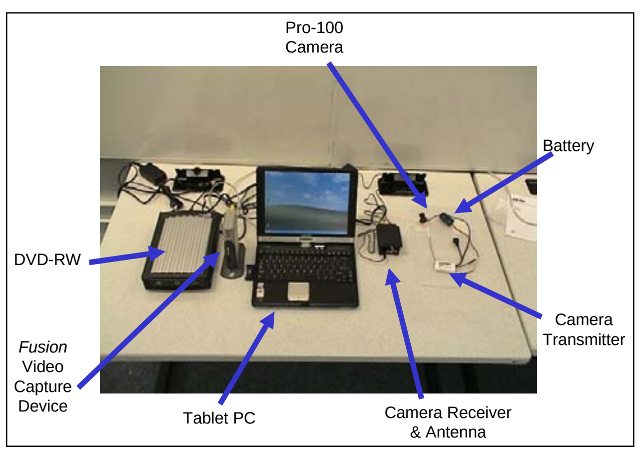

Figure 1 – Video Capture System Components

The following sections provide a more detailed description of the components. The appendices found at the end of this paper provide technical specifications for each of the components as well.

Video Camera

The video camera that we used on this project is part of the Pro 100 video camera system built by the Hi Cam Corporation in Australia. The camera is light weight at 0.46 ounces, yet is built with Charge Coupled Device (CCD) technology as the standard. The CCD type of image sensor is preferred to Complementary Metal Oxide Semiconductor (CMOS) technology because CCD was developed specifically for imaging applications. CMOS is a newer technology being applied to imaging that may gain popularity in the future, but CCD is preferable at this time.

Figure 2 – Pro 100 Video Camera

The camera, shown in Figure 2, is enclosed in a housing that allows for easy installation on the UAV. As purchased, it is already connected to the transmitter that will also be mounted on the UAV. The resolution of the camera is limited to 330 X 350 pixels. This resolution limits the size of the video picture that can be displayed and results in a fairly noticeable “soda straw” effect on the video. That is, the field of view provide by the camera is fairly limited.

Figure 2 shows the Pro 100 CCD video camera. The camera runs off a 4.8V battery connected to the Pro 100 system, and the camera’s power consumption is 160 mA.

Video Transmitter and Receiver

The Pro 100 video camera system also includes a video transmitter and receiver. The transmitter comes connected to the camera and is enclosed in a shrink-wrap package that is suitable for mounting in the UAV. It is light-weight as well, weighing only 1.48 ounces. The transmitter includes an on/off switch that is convenient for flight operations and can be easily checked as part of the pre-flight payload checklist. The transmitter and camera require an onboard 4.8V batterythat weighs 1.9 ounces and is rated at 800 mA. The power consumption of the transmitter is 120 mA, so combined

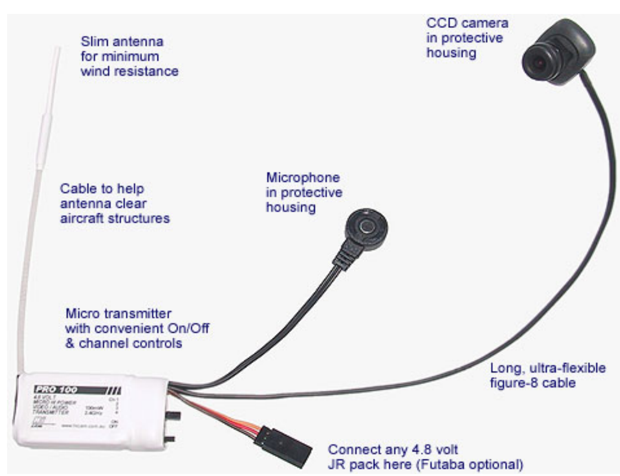

Figure 3 – Pro 100 Video Transmitter

with the camera, the total power consumption of the Pro 100 system is 280 mA. With the 800 mA battery, we expect the system to maintain power for almost three hours.

The transmitter, shown in Figure 3, is capable of sending video signals down four separate channels all approximately in the 2.4 GHz frequency range. Appendix B at the end of this paper gives the exact frequencies for these channels. The channel is selected with a switch on the transmitter. Having four channels is useful when considering flying more than one UAV at a time. If we were to fly multiple UAVs, we could fly up to four at one time, each one on a separate video channel. In this way, we could transmit video from up to four UAV simultaneously.

Figure 4 – Pro 100 Video Receiver

The Pro 100 system also includes a receiver and antenna to be used on the ground to receive the video transmissions as shown in Figure 4. The receiver must be tuned to one of the four channels provided and the antenna oriented properly to receive the best quality signal from the transmitter. A four position switch on the receiver is used to tune to the proper channel The receiver includes three RCA jacks providing output for video, left audio, and right audio. It is powered by a 12V DC power supply, and we used a 110V AC/DC converter to power the receiver.

Video Capture Device

In order to connect the video signal from the video receiver to the computer, we used the Dazzle Fusion video capture device.

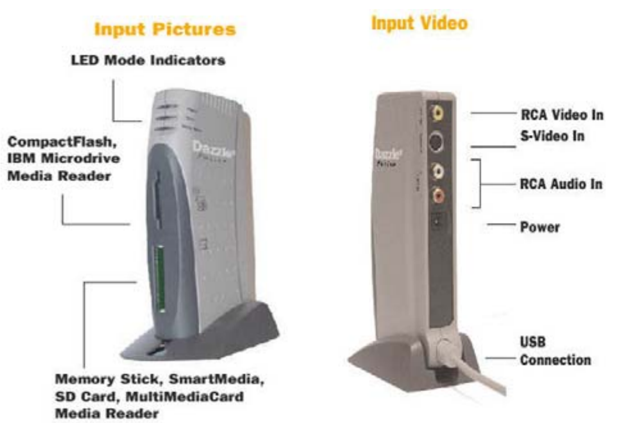

Figure 5 – Dazzle Fusion Video Capture Device

This device, shown in Figure 5, is capable of capturing still frames or video signals. The video receiver is connected to this device using standard RCA audio and video cables, as shown in Figure 5. There is also an S-Video jack available. In order to capture videos using this device, we had to use software provided with the system as described below.

2.4 Video Capture Software

The UAVRG currently owns a license to CapturePro version 3.0, which is video capture software. This software includes several sample application programs written in both C++ and C#. We used the C# application to test the system installation and to capture video during UAV flights. This software included several errors that would cause the application to crash unexpectedly, but it worked well enough to conduct system tests.

The software application, shown in Figure 6, allows the user to connect to the Dazzle Fusion video capture device and turn on a preview window on the computer. As shown in Figure 6, the preview window provides a real-time feed from the video camera when the system is working. This provides a quick end-to-end system test for the video capture system from the camera through the transmitter and receiver to the video capture device into the software.

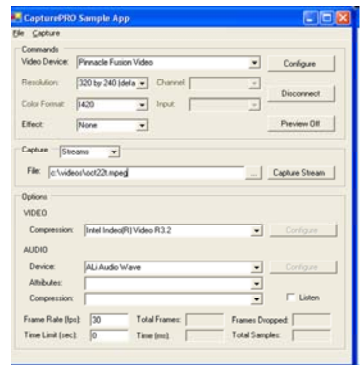

Figure 6 – Video Capture Software Application

The software also allows the user to select which of several video compression-decompression (codec) algorithms to use for video capture. This particular aspect of this project proved to be quite interesting. The codec selected for video capture is directly correlated to the file size of the resulting captured video file. The cadets in CS 453, Software Engineering I, have collected data on these codecs and the results of these studies are included in the Testing section below.

3 Mounting the Camera

Once the system was functioning properly on the laboratory bench, we proceeded to mount the camera onto an existing UAV. The particular UAV that we used for this project is the Extra Easy 2 remote-controlled model airplane that we have modified for autonomous flight. The Extra Easy 2 UAV, shown in Figure 7, weighs approximately seven pounds. It is a bit sluggish at this altitude when loaded down with an auto-pilot, 12V battery, and fuel. We have modified the airplane adding a larger engine for more power.

Figure 7 – Extra Easy 2 UAV

We chose to mount the video camera just aft of the nose gear in a straight down orientation. It is a fixed mount with no way to slew or focus the camera in flight. The camera does have a manual focus that can be adjusted before flight.

Figure 8 – Camera Location

Figure 8 shows the general location of the camera mount on the underside of the Extra Easy 2. It's hard to see in the Figure, but the camera lens is the small black circle in the middle of the raised white section aft of the nose wheel.

Figure 9 shows a close-up of the camera mount. Here you can see the camera lens more clearly. With this mount, we were still able to manually focus the camera before flight. As suggested in the video camera user's manual, we applied lock tight fluid to the threads of the camera focus and set the focus at infinity.

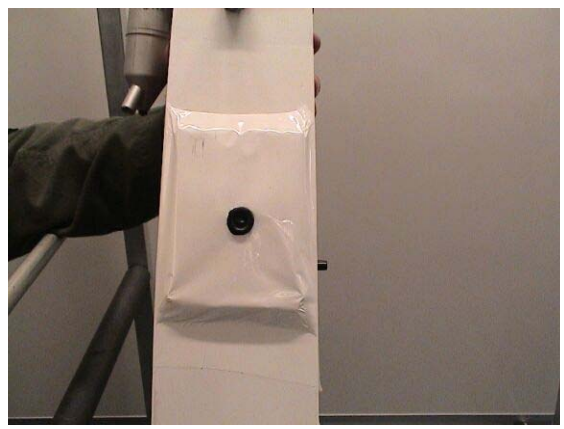

Figure 9 – Camera Mount Close-up

Inside the aircraft, the camera housing protrudes from the bottom of the fuselage up into the payload bay. Figure 10 shows an inside view of the payload bay including the camera mount. The figure also shows where we mounted the video transmitter on the side of the payload bay and the onboard battery. Since the entire video camera system with battery is less than five ounces in weight, the location of the transmitter and battery were of little impact on the weight and balance of the UAV.

Once the camera was mounted and the overall system was tested end-to-end in the lab, we were ready for flight testing with the UAV.

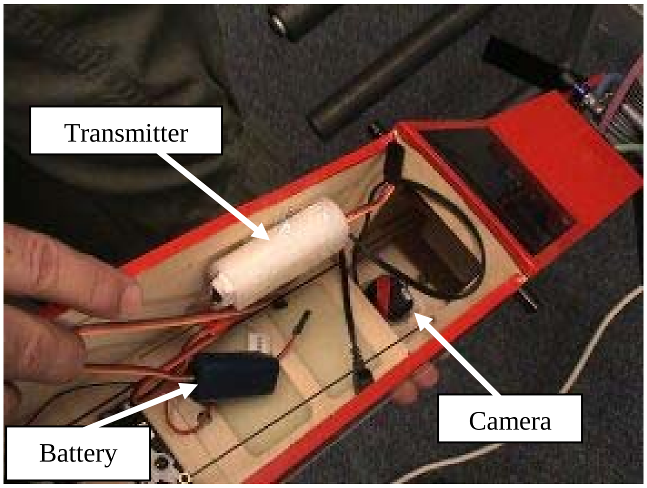

Figure 10 – Camera in Payload Bay

4 Testing

As mentioned in the section on video capture software, there are numerous codecs available for video capture. In fact, the CapturePro 3.0 software includes over 30 different codecs available for video capture. Each codec uses its own algorithm for compressing the video image and storing it on the computer's hard drive. To view the video, that specific codec must be available in the video playback software such as Windows Media Player or Real Player.

In order to test the different codecs, four cadets from the Software Engineering course ran several tests collecting data on the codecs. The first phase of their testing was to capture video in the UAV lab using different codecs. For each codec that they tested, they captured one minute of video using the video capture software on the computer. They then recorded the file size for the video clip and compared the different file sizes for the codecs.

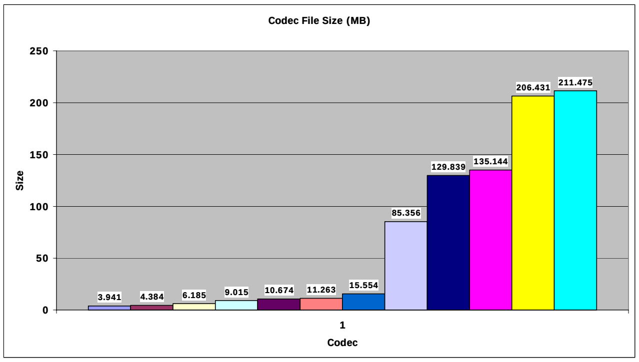

Figure 11 shows the data from their codec testing. As you can see in the figure, the file sizes for the one minute video clips ranged from a few MB to hundreds of MBs. The quality of the captured video is directly correlated to the file size, i.e. the larger the file size the better the video quality.

(Note: A larger version is at the end of the paper)
Figure 11 – Codec File Sizes

As part of their testing, the cadets selected three candidate codecs that produced reasonable video images and did not take large file sizes to store.

Figure 12 shows the file sizes for the three top codec candidates as chosen by the cadets. The one that they reported gave the best quality of these codecs is the Indeo Video 510 codec. We would suggest using this codec for UAV video capture flights in the future.

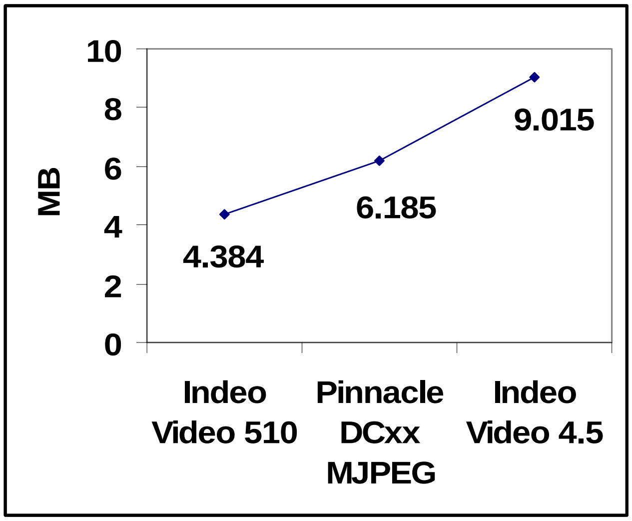

Figure 12 – Top Three Codec File Sizes

Conclusion and Future Directions

The initial purpose of the project was to integrate a video capture system onto a UAV and capture video in flight. The intent was to incorporate the results of this project into the Software Engineering I year-long project. We have met that goal and will continue to use the video capture system throughout the year.

Future studies with video capture systems could easily continue the cadets' work on comparing video codecs. This particular part of the project proved to be surprisingly significant to the overall project. Depending on the codec that we used for the video capture our video clips for even short flights could range from 100 MB to over 1.5 GB of disk space.

The video image captured from this particular camera was on the order of 300X300 pixel resolution. The transmitter and receiver provided only around 2000' of coverage. Future research could explore better quality cameras such as 1000X1000 pixel resolutions and the resulting file sizes from these video images. It could also explore better video transmitters and receivers to gain better coverage from the UAV during flight.

The appendices provided at the end of this report give technical specifications for each part of the video capture system.

Overall, this project has been a valuable step in our UAV research. The authors and the cadets in the Software Engineering class have learned many things about integrating a video capture system onto a UAV.

6 References

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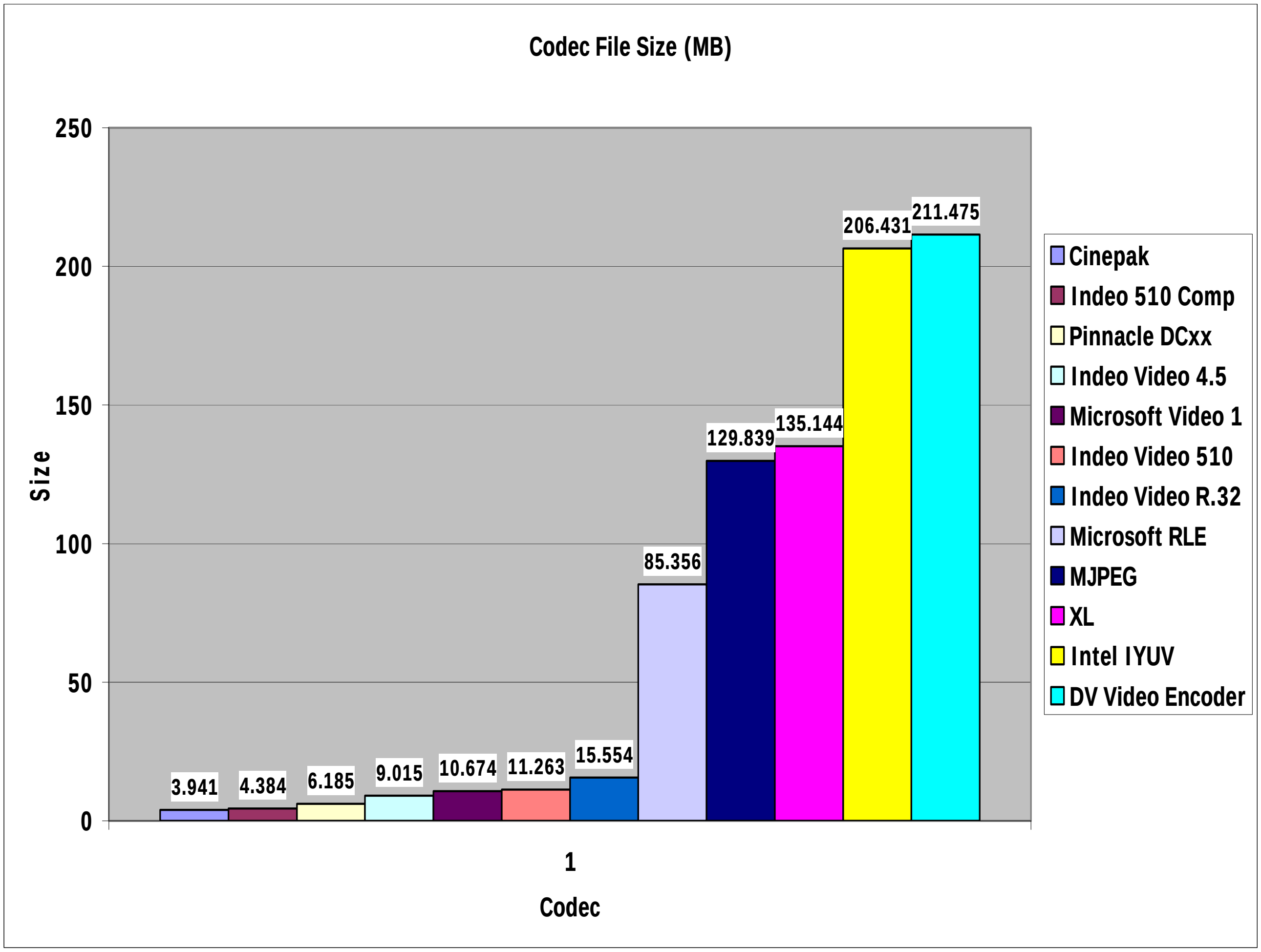


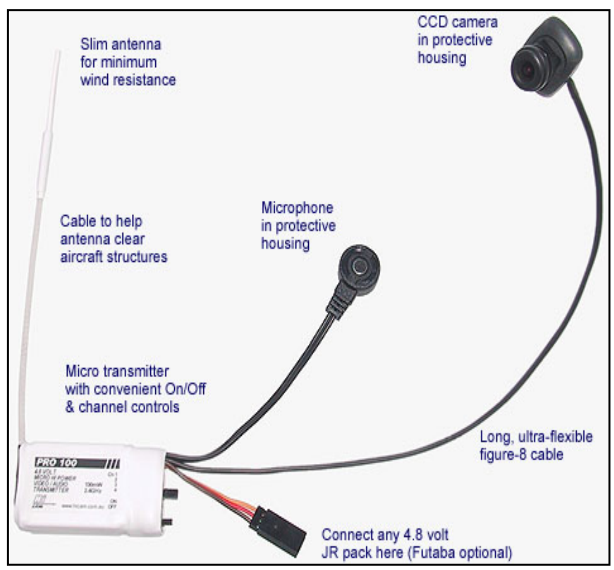
Figure 11 – Codec File Sizes

Appendix A

Technical Specifications

Onboard Video Camera

Dimensions	30mm(W) x 24mm(H) x 30mm(D)
Weight	13g (0.46 oz) including housing
Imaging System	¼" CCD color camera
Lens	3.8mm wide angle, adjustable focus
Available TV formats	NTSC or PAL
CCD Resolution	330 horizontal, 350 vertical
Minimum Illumination	5 Lux with filter removed
Voltage Required	4.4-5.6 Volts DC
Current consumption	160mA @ 5V



Appendix B

Technical Specifications

Video Transmitter

Dimensions	60mm(W) x 30mm(H) x 10mm(D)
Weight	42g (1.48 oz)
RF output power	100mW
Channel Frequencies	2.414, 2.432, 2.450, 2.468 GHz
Modulation type	FM
Video input	1 Volt p/p 75 Ohm composite
Audio input	Line Level (pre-amped mic included)
Voltage required	4.0 – 5.6 volts DC
Current	120mA +/- 10% @ 5V
Supplied Antenna	Omni-directional coaxial dipole patch (5dBi)
On-board switches	On-off switch & channel switch
Power connector	JR / HiTec
Range	up to 2000 feet

Video Receiver

Antenna Connector	SMA, 50 Ohm
Video Output	RCA, 1 Volt p/p 75 Ohm
Audio Output	Line Level
Channel Frequencies	2.414, 2.432, 2.450, 2.468 GHz
Modulation type	FM
Sensitivity	-85 dBm
Voltage required	9-12 Volts DC
Current consumption	210 mA
Supplied Antenna	Flat

Appendix C

Technical Specifications

Onboard Battery

Dimensions	1.85" x 0.82" x 0.82" for block style
	1.77" x 1.57" x 0.39" for flat style
Weight	1.9 ounces
Type	Nickel Metal Hydride (NiMH)
Cells	4 @ 1.2V each
Connector	JR/HiTech
Voltage	4.8 Volts DC
Current available	800 mA
Charger	Any for 4.8V NiMH

Appendix D

Technical Specifications

Dazzle Fusion Video Capture Device

Video Input	S-Video, composite analog video in
Audio Input	Stereo RCA audio in
Computer Interface	USB interface; works with USB 1.0 and USB 2.0 machines
Compression formats	AVI, MPEG-1, MPEG-2, RealVideo, or Windows Media Format
Image capture ports	CompactFlash™ Type I & II, Memory Stick™, SmartMedia™, MulitMediaCard™
Software	SD Card™ and IBM Microdrive™ Timeline-based authoring for DVD, VCD, and S-VCD

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